Gas Hydrates: Resource and Hazard

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Summary

Solid gas hydrates are a potentially huge source of natural gas for the United States. Gas hydrates occur naturally onshore in some permafrost regions, and at or below the seafloor in sediments where water and gas combine at low temperatures and high pressures to form an ice-like solid substance, in which frozen water molecules form a cage-like structure around high concentrations of natural gas, or methane. The Bureau of Ocean Energy Management within the Department of the Interior estimated a mean value of over 51,000 trillion cubic feet (TCF) of in-place gas hydrates combined for the Outer Continental Shelf off the U.S. Atlantic and Pacific coasts and Gulf of Mexico. However, the in-place estimate disregards technical or economical recoverability, and likely overestimates the amount of commercially viable gas hydrates. To date, gas hydrates have no confirmed commercial production.

The U.S. Geological Survey estimated that there are about 85 TCF of technically recoverable gas hydrates in northern Alaska. By comparison, U.S. consumption of natural gas was 25 TCF in 2012. An issue for the 113th Congress is whether gas hydrates represent a viable component of the future energy portfolio of the United States, and if federal research and development programs are appropriate and sufficient to meet energy policy goals.

Gas hydrates are also a risk, representing a hazard to oil and gas drilling and production. If gas hydrates dissociate suddenly and release expanded gas during offshore drilling, they could disrupt marine sediments and compromise pipelines and production equipment. The tendency of gas hydrates to dissociate and release methane, which can be a hazard, is the same characteristic that research and development efforts strive to enhance so that methane can be produced and recovered in commercial quantities.

Gas hydrates hindered early attempts to plug the Deepwater Horizon oil well blowout in the Gulf of Mexico and to siphon the leaking oil and gas to the surface. Given the potential risk associated with developing the resource, Congress may consider whether to evaluate the evolving regulatory and safety infrastructure for offshore development to determine if it is appropriate for exploiting gas hydrates offshore.

Developing gas hydrates into a commercially viable source of energy is a goal of the U.S. Department of Energy (DOE) methane hydrate program, initially authorized by the Methane Hydrate Research and Development Act of 2000 (P.L. 106-193). The Energy Policy Act of 2005 (P.L. 109-58) extended the authorization of appropriations through FY2010. Since 2005, DOE has spent approximately $79 million on gas hydrate research and development through FY2013. The Obama Administration requested $5 million for gas hydrate R&D in FY2014.

In 2012, DOE funded a field trial conducted by ConocoPhillips on the North Slope of Alaska, which successfully recovered methane from gas hydrates using two different methods. In 2013, Japan's Oil, Gas and Metals National Corporation, announced that it had produced methane from gas hydrate deposits 300 meters below the seafloor in the Eastern Nankai Trough off the east coast of Japan. According to company reports, this was the first test conducted of offshore gas hydrate production. Both tests represented just a few days of production, and it appears that further work is needed before gas hydrates can be commercially exploited in permafrost regions and below the seafloor.

Contents

Figures

Contacts

Introduction

Gas hydrates are a potentially huge if uncertain global energy resource. Some estimates of the global potential resource for gas hydrates are 100,000 trillion cubic feet (TCF) or more for *gas-in-place* (meaning every molecule of gas hydrate, not necessarily what is technically or economically recoverable).[1] However, attempts to constrain these estimates over the past several decades have not succeeded; even recent estimates range over three orders of magnitude.[2] Further, gas hydrates have no confirmed commercial production to date. Given technical and economic considerations, there is likely a vast difference between the amount of gas hydrate actually in place and what can be technically and commercially produced.

The United States and other countries with territory in the Arctic or with offshore gas hydrates along their continental margins are interested in developing the resource. Countries currently pursuing national research and development programs include Japan, India, South Korea, and China, among others. Although burning natural gas produces carbon dioxide (CO_2), a greenhouse gas, the amount of CO_2 liberated per unit of energy produced is less than 60% of the CO_2 produced from burning coal.[3] Increasing the U.S. supply of natural gas from gas hydrates would decrease reliance on imported gas and reduce U.S. emissions of CO_2 if domestically produced gas hydrates substitute for coal as an energy source.

Globally, according to one estimate, the amount of gas hydrate yet to be found offshore along continental margins probably exceeds the amount already identified onshore in permafrost regions by two orders of magnitude.[4] With the exception of the assessments discussed below, none of the global gas hydrate estimates are well defined, and all are speculative to some extent.[5] One way to depict the potential size and producibility of global gas hydrate resources is by using a resource pyramid (**Figure 1**).[6] The apex of the pyramid shows the smallest but most promising gas hydrate reservoir—arctic and marine sandstones—which may host tens to hundreds of TCF of gas hydrates. The bottom of the pyramid shows the largest but most technically and economically challenging reservoir—marine shales.

[1] Ray Boswell and Timothy S. Collett, "Current Perspectives on Gas Hydrate Resources," *Energy Environ. Sci.*, vol. 4 (September 14, 2010), pp. 1206-1215. For comparison, the United States consumed approximately 25 TCF of natural gas in 2012.

[2] Ibid., Figure 1.

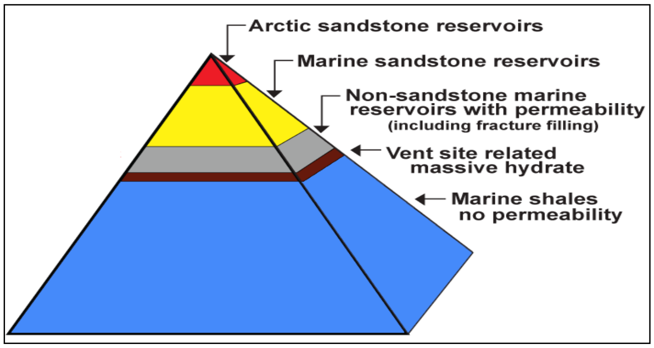
[3] U.S. Department of Energy, Energy Information Agency (EIA), at http://www.eia.doe.gov/cneaf/coal/quarterly/co2_article/co2.html.

[4] George J. Moridis et al., "Toward production from gas hydrates: current status, assessment of resources, and simulation-based evaluation of technology and potential," 2008 SPE Unconventional Reservoirs Conference, Keystone, CO, February 10, 2008, p. 3, at http://www.netl.doe.gov/technologies/oil-gas/publications/Hydrates/reports/G308_SPE114163_Feb08.pdf.

[5] Ibid.

[6] Roy Boswell and Timothy S. Collett, "The Gas Hydrate Resource Pyramid," *Fire in the Ice*, Methane Hydrate R&D Program Newsletter, Fall 2006, pp. 5-7, at http://www.netl.doe.gov/technologies/oil-gas/FutureSupply/MethaneHydrates/newsletter/newsletter.htm.

Figure 1. Gas Hydrate Reservoir Pyramid



Source: Roy Boswell and Timothy S. Collett, "The Gas Hydrate Resource Pyramid," *Fire in the Ice*, Methane Hydrate R&D Program Newsletter, Fall 2006.

Sandstones are considered superior reservoirs because they have much higher permeability—they allow more gas to flow—than shales, which can be nearly impermeable. The marine shale gas hydrate reservoir may host hundreds of thousands of TCF, but most or all of that resource may never be economically recoverable. It is likely that continued research and development efforts in the United States and other countries will focus on producing gas hydrates from arctic and marine sandstone reservoirs.

Policy Considerations

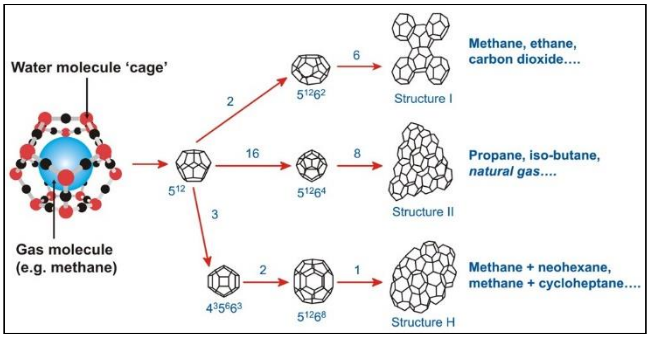
U.S. policy regarding energy resource development is a perennial issue for Congress. Given that gas hydrates offer the possibility of substantially increasing the U.S. supply of natural gas, the 113th Congress may evaluate whether U.S. policies regarding onshore and offshore development are appropriate for the gas hydrate resource. The 113th Congress may also consider the risks of developing gas hydrates, particularly offshore in the Gulf of Mexico, in the wake of the Deepwater Horizon blowout and oil spill. In part, the federal research and development (R&D) program for gas hydrates is aimed at developing knowledge and technology to allow commercial production of methane from gas hydrates and to minimize the risks of developing the resource. Questions for consideration may include: What has the program accomplished since the Methane Hydrate Research and Development Act of 2000 (P.L. 106-193) was enacted? Are the funding levels appropriate for the program? Has the outlook for the commercial production of gas hydrates changed as production of onshore shale gas resources has increased since P.L. 106-193 was enacted?

The 113th Congress may also consider market forces in addition to federal involvement in the development of gas hydrates. Together with advances in the technology to efficiently produce gas hydrates, the economic viability of gas hydrates will depend on the relative cost of conventional fuels and other sources of natural gas, such as shale gas, as well as other factors such as pipelines and other infrastructure needed to deliver gas hydrate methane to market. Additionally, price volatility of natural gas will likely affect the level and continuity of private-sector investment in commercial production of gas hydrates. Countries other than the United States lacking large domestic onshore natural gas resources, such as Japan or India, may have additional incentive to pursue research and development and commercial production of offshore gas hydrates.

What Are Gas Hydrates?

Gas hydrates occur naturally onshore in some permafrost regions, and at or below the seafloor in sediments where water and gas combine at low temperatures and high pressures to form an ice-like solid substance.[7] Methane, the primary component of natural gas, is typically the dominant gas in the hydrate structure. In a gas hydrate, frozen water molecules form a cage-like structure around high concentrations of natural gas. (See **Figure 2**.) The gas hydrate structure is very compact. When heated and depressurized to temperatures and pressures typically found on the Earth's surface (one atmosphere of pressure and 70º Fahrenheit), its volume expands by 150 to 170 times. Thus, one cubic foot of solid gas hydrate found underground in permafrost or beneath the seafloor would produce between 150 and 170 cubic feet of natural gas when brought to the surface.[8]

Figure 2. Molecular Structure of the Gas Hydrate Molecule



Source: Centre for Gas Hydrate Research, Heriot Watt Institute for Petroleum Engineering, Heriot Watt University, http://www.pet.hw.ac.uk/research/hydrate/hydrates_what.cfm.

Gas Hydrate Resources

There are several challenges to commercially exploiting gas hydrates. How much and where gas hydrates occur in commercially viable concentrations are not well known, and how the resource can be extracted safely and economically is a current research focus. Reports of vast gas hydrate resources can be misleading unless those estimates are qualified by the use of such terms as *in-place* resources, technically recoverable resources, and proved reserves.

- The term *in-place* is used to describe an estimate of gas hydrate resources without regard for technical or economical recoverability. Generally these are the largest estimates.
- Undiscovered technically recoverable resources are producible using current technology, but this does not take into account economic viability.
- Proved reserves are estimated quantities that can be recovered using current technology under existing economic and operating conditions.

[7] The terms *methane hydrate* and *gas hydrate* are often used interchangeably, and refer to the methane-water crystalline structure called a clathrate.

[8] Values given below for estimates of gas hydrate resources refer to the quantity of natural gas potentially developed from the solid hydrate, not the actual volume of the gas hydrate in solid form.

For example, the U.S. Department of Energy's Energy Information Agency (EIA) estimates that in 2009 the total undiscovered technically recoverable dry[9] natural gas resources in the United States were approximately 2,200 TCF, but proved reserves were only 273 TCF.[10] This is an important distinction because there are no proved reserves for gas hydrates at this time. Gas hydrates have no confirmed past or current commercial production. For perspective, the United States consumed over 25 TCF of natural gas in 2012.[11]

The Department of the Interior's U.S. Geological Survey (USGS) and Bureau of Ocean Energy Management (BOEM, formerly the Minerals Management Service, MMS) typically report only in-place estimates of U.S. gas hydrate resources. For example, in 2008 BOEM estimated that the mean in-place gas hydrate resources in the Gulf of Mexico outer continental shelf were approximately 21,400 TCF.[12] In 2012, BOEM combined that estimate with an assessment of the in-place gas hydrate resources of the entire U.S. outer continental shelf (excluding Alaska), for a total mean estimate of approximately 51,300 TCF.[13]

On November 12, 2008, the USGS produced a first-ever estimate of undiscovered technically recoverable gas hydrates. The USGS examined portions of northern Alaska, and the resulting estimate probably represents the most robust effort to-date for identifying gas hydrates that may be commercially viable sources of energy.[14] Despite a lack of a production history and only limited field testing, the USGS report cites a growing body of evidence indicating that some gas hydrate resources, such as those in northern Alaska, might be produced with existing technology.

Gas Hydrates on the North Slope, Alaska

The USGS assessment indicates that the North Slope of Alaska may host about 85 TCF of undiscovered technically recoverable gas hydrate resources (**Figure 3**). According to the report, technically recoverable gas hydrate resources could range from a low of 25 TCF to as much as 158 TCF on the North Slope.[15] Again, total U.S. consumption of natural gas in 2012 was slightly more than 25 TCF.[16]

Of the mean estimate of 85 TCF of technically recoverable gas hydrates on the North Slope, 56% is located on federally managed lands, 39% on lands and offshore waters managed by the state of Alaska, and the remainder on Native lands.[17] The total area covered by the USGS assessment is

[9] "Dry" natural gas refers to gas that is predominantly composed of methane. "Wet" natural gas means that in addition to methane, other compounds such as ethane and butane are present.

[10] See U.S. Energy Information Administration, http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0401, and http://www.eia.gov/dnav/ng/ng_enr_dry_a_EPG0_r11_bcf_a.htm.

[11] U.S. Energy Information Administration, *Natural Gas Consumption by End Use*, July 31, 2013, http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm.

[12] Matthew Frye, *Preliminary Evaluation of In-Place Gas Hydrate Resources: Gulf of Mexico Outer Continental Shelf*, Minerals Management Service, MMS 2008-004, February 1, 2008, http://www.boem.gov/uploadedFiles/BOEM/Oil_and_Gas_Energy_Program/Resource_Evaluation/Gas_Hydrates/MMS2008-004.pdf.

[13] BOEM Fact Sheet RED-2012-01, "Assessment of In-Place Gas Hydrate Resources of the Lower 48 United States Outer Continental Shelf," 2012.

[14] USGS Fact Sheet 2008-3073, *Assessment of Gas Hydrate Resources on the North Slope, Alaska*, 2008, at http://pubs.usgs.gov/fs/2008/3073/.

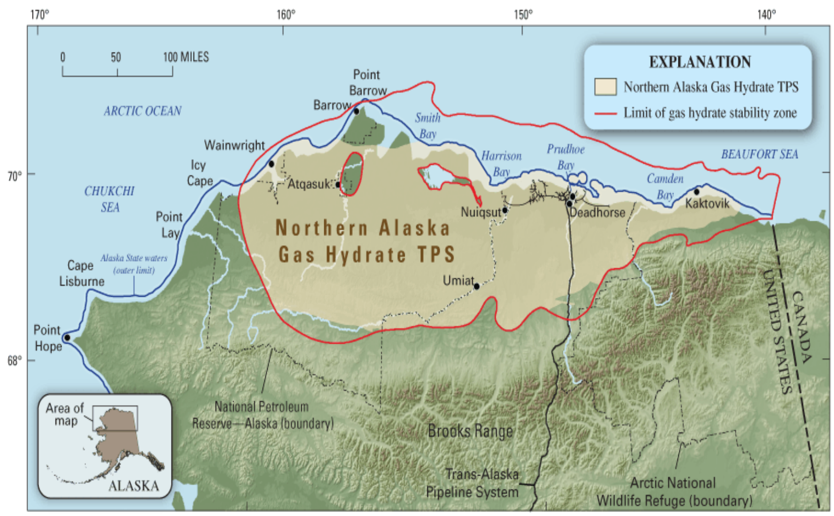
[15] In their estimate, the USGS provides a 95% probability that at least 25 TCF is recoverable; a 5% probability that at least 158 TCF is recoverable; and a mean probability estimate of approximately 85 TCF.

[16] U.S. Energy Information Administration, *Natural Gas Consumption by End Use*, http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm.

[17] USGS presentation, Timothy S. Collett, October 2008, at http://energy.usgs.gov/flash/AlaskaGHAssessment_slideshow.swf.

55,894 square miles, and extends from the National Petroleum Reserve in the west to the Arctic National Wildlife Refuge (ANWR) in the east (**Figure 3**). The area extends north from the Brooks Range to the state-federal offshore boundary 3 miles north of the Alaska coastline. Gas hydrates might also be found outside the assessment area; the USGS reports that the gas hydrate stability zone—where favorable conditions of temperature and pressure coexist for gas hydrate formation—extends beyond the study boundaries into federal waters beyond the three-mile boundary.

Figure 3. Gas Hydrate Assessment Area, North Slope, Alaska



Source: USGS Fact Sheet 2008-3073, Assessment of Gas Hydrate Resources on the North Slope, Alaska, 2008, at http://pubs.usgs.gov/fs/2008/3073/.

Note: TPS refers to total petroleum system, which refers to geologic elements that control petroleum generation, migration, and entrapment.

Gas Hydrates in Outer Continental Shelf of the Lower 48 United States

Gas hydrates in the Outer Continental Shelf (OCS) represent a potential source of natural gas in addition to the considerable resource base already estimated to exist offshore the U.S. Atlantic, Pacific, and Gulf of Mexico coastlines. In 2011 the Bureau of Ocean Energy Management (BOEM) estimated that the undiscovered technically recoverable natural gas resources for the Atlantic, Pacific, and Gulf of Mexico OCS totaled a mean value of 264 TCF.[18] The BOEM estimate for the Alaska OCS would add an additional 131 TCF mean value. These values are difficult to compare against gas hydrate estimates for the OCS because only *in-place* estimates are available for the OCS, and are typically much higher than undiscovered technically recoverable estimates. Even the technically recoverable gas hydrate resources assessed by the USGS (discussed above) are difficult to compare to conventional natural gas assessments in part because gas hydrates have never been produced commercially. Nevertheless, *in-place* estimates represent a first-order approximation of the potential gas hydrate resource available in the OCS.

[18] Bureau of Ocean Energy Management, *Assessment of Undiscovered Technically Recoverable Oil and Gas Resources of the Nation's Outer Continental Shelf*, 2011, BOEM Fact Sheet RED-2011-01a, November 2011, http://www.boem.gov/uploadedFiles/2011_National_Assessment_Factsheet.pdf.

Gulf of Mexico

On February 1, 2008, BOEM (then MMS) released an assessment of gas hydrate resources for the Gulf of Mexico.[19] The report gave a statistical probability of the volume of undiscovered *in-place* gas hydrate resources, with a mean estimate of over 21,000 TCF. The MMS report estimated how much gas hydrate may occur in sandstone and shale reservoirs, using a combination of data and modeling, but did not indicate how much is recoverable with current technology. The report noted that porous and permeable sandstone reservoirs have the greatest potential for actually producing gas from hydrates, and gave a mean estimate of over 6,700 TCF of sandstone-hosted gas hydrates, about 30% of the total mean estimate for the Gulf of Mexico.[20] Even for sandstone reservoirs, however, the in-place estimates for gas hydrates in the Gulf of Mexico likely far exceed what may be commercially recoverable with current technology.

In 2009, drilling by a government and industry consortium in the Gulf of Mexico revealed the presence of gas hydrate-bearing reservoir rocks with the potential for producing natural gas using conventional technology.[21] The drilling project identified gas hydrates in sand reservoirs, thick sequences of fracture-filling gas hydrates in shales, and gas hydrates in other types of systems. In a press release, USGS stated that the discovery of the thick, gas-bearing sands provides increased confidence in assessing the energy resource potential of marine gas hydrates.[22]

Atlantic and Pacific Outer Continental Shelf

Using a similar methodology to the Gulf of Mexico assessment, in a 2012 report BOEM estimated the amount of undiscovered in-place natural gas resources within the limits of the 200-mile Exclusive Economic Zone (EEZ) off the Atlantic and Pacific Outer Continental Shelves.[23] The report indicated a mean value of 21,700 TCF of in-place gas hydrate resource along the Atlantic OCS, and a mean value of 8,190 TCF along the Pacific OCS. In its report, BOEM indicated that its resource assessment provided lower values than a 1995 USGS assessment,[24] reflecting variations in the modeling approach by these studies, but also because of information garnered from gas hydrate field programs conducted since the USGS study.[25]

Gas Hydrate Hazards

The existence of gas hydrates sometimes presents a significant hazard for conventional oil and gas drilling and production operations.[26] Oil and gas wells drilled through permafrost or offshore

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[19] U.S. Department of the Interior, Minerals Management Service, Resource Evaluation Division, "Preliminary evaluation of in-place gas hydrate resources: Gulf of Mexico outer continental shelf," OCS Report MMS 2008-004 (February 1, 2008), at http://www.mms.gov/revaldiv/GasHydrateFiles/MMS2008-004.pdf. This report, and the estimates for the Atlantic and Pacific Outer Continental Shelf (discussed below), refer to the areas adjacent to the Lower 48 states and within the limits of the 200 nautical mile U.S. Exclusive Economic Zone (EEZ).

[20] Ibid., Table 16.

[21] USGS press release, "Significant Gas Resource Discovered in U.S. Gulf of Mexico," May 29, 2009, at http://www.usgs.gov/newsroom/article.asp?ID=2227&from=rss_home.

[22] Ibid.

[23] [23] BOEM Fact Sheet RED-2012-01.

[24] T. S. Collett, *Gas Hydrate Resources of the United States*, U.S. Geological Survey, *in* 1995 National Assessment of United States Oil and Gas Resources, U.S. Geological Digital Data Series 30.

[25] Ibid.

[26] Timothy S. Collett and Scott R. Dallimore, "Detailed analysis of gas hydrate induced drilling and production

to reach conventional oil and gas deposits may encounter gas hydrates. Companies generally try to avoid gas hydrate zones because they lack a detailed understanding of the mechanical and thermal properties of the gas hydrate-bearing sediments.[27] However, to mitigate the potential hazard in these instances, the wells are cased—typically using a steel pipe that lines the wall of the borehole—to separate and protect the well from the gas hydrates in the shallower zones as drilling continues deeper. Unless precautions are taken, continued drilling may heat up the sediments surrounding the wellbore, causing gas from the dissociated hydrates to leak and bubble up around the casing. Once oil production begins, hot fluids flowing through the well could also warm hydrate-bearing sediments and cause dissociation. The released gas may pool and build up pressure against the well casing, possibly causing damage.[28]

Offshore drilling operations that disturb gas hydrate-bearing sediments could fracture or disrupt the bottom sediments and compromise the wellbore, pipelines, rig supports, and other equipment involved in oil and gas production from the seafloor.[29] Problems may differ somewhat between onshore and offshore operations, but they stem from the same characteristic of gas hydrates: decreases in pressure and/or increases in temperature can cause the gas hydrate to dissociate and rapidly release large amounts of gas into the wellbore during a drilling operation.

Gas hydrate production is hazardous in itself. For activities in permafrost, two general categories of problems have been identified: (1) uncontrolled gas releases during drilling; and (2) damage to well casing during and after installation of a well. Some observers suggest that exploiting the gas hydrate resources by intentional heating or by depressurization poses the same risks—requiring mitigation—as drilling through gas hydrates to reach deeper conventional oil and gas deposits.[30]

hazards," Proceedings of the Fourth International Conference on Gas Hydrates, Yokohama, Japan, April 19-23, 2002.

[27] George J. Moridis and Michael B. Kowalsky, "Geomechanical implications of thermal stresses on hydrate-bearing sediments," Fire in the Ice, Methane Hydrate R&D Program Newsletter, Winter 2006.

[28] Collett and Dallimore (2002).

[29] Moridis and Kowalski (2006).

[30] Personal communication, Ray Boswell, Manager, Methane Hydrate R&D Programs, DOE National Energy Technology Laboratory, Morgantown, WV, November 5, 2008.

Gas Hydrates and the Deepwater Horizon Oil Spill in the Gulf of Mexico

On April 20, 2010, a well drilled by the Deepwater Horizon semisubmersible oil platform "blew out," igniting a fire on board the platform, which eventually sank. The blowout resulted in an uncontrolled leak of oil and gas from the broken off pipe, or "riser," that led from the top of the well to the drilling platform. In one of the early attempts to plug the well, a heavy steel and concrete box was lowered atop the leaking riser in an attempt to capture the oil and gas and siphon it to the surface. The attempt failed because hydrates clogged the valves and pipes leading to the surface from the steel box as methane converted from a gas phase to solid phase methane hydrate.

The Deepwater Horizon had drilled an "ultradeep" exploratory well in the Gulf of Mexico in approximately 5,000 feet of water. At 5,000 feet below the surface, seawater is approximately 40^{0} F (4.4^{0} C), and the pressure is approximately 2,500 pounds per square inch (psi). Gas hydrates are stable at that depth and pressure, and can form as long as sufficient quantities of natural gas and water are present—as was the case for the Deepwater Horizon blowout. (For reference, the pressure at sea level, corresponding to one atmosphere, is approximately 14.7 psi.)

The final report from the Deepwater Horizon Commission on the disaster mentioned the risk from methane hydrates to deepwater drilling, citing the possibility of disturbing hydrate-bearing sediments during drilling. The report did not, however, indicate that hydrates in the marine sediments had any role in causing the blowout and loss of well control.

Sources: Personal communication, Carolyn Ruppel, Gas Hydrates Project, U.S. Geological Survey, Reston, VA, May 17, 2010; MMS Report 2008-004, *Preliminary Evaluation of In-Place Gas Hydrate Resources: Gulf of Mexico Outer Continental Shelf*; National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, *Deep Water: the Gulf Oil Disaster and the Future of Offshore Drilling*, Report to the President, January 2011.

Gas Hydrate Research and Development

Spending on Gas Hydrates at DOE

A goal of the DOE methane hydrate research and development (R&D) program is to develop knowledge and technology to allow commercial production of methane from gas hydrates by 2015.[31] The Methane Hydrate Research and Development Act of 2000 (P.L. 106-193) first authorized appropriations for the program of $5 million in FY2001 and increased the annual authorization of appropriations to $12 million by FY2005. The Energy Policy Act of 2005 (P.L. 109-58) authorized appropriations from FY2006 through FY2010 totaling $155 million for the program over five years. Authorization of appropriations for the program expired at the end of FY2010.

Since P.L. 109-58 reauthorized appropriations for the program in 2005, DOE has spent approximately $79 million on the R&D program in eight years through FY2013.[32] DOE allocated $4.8 million to the program in FY2013, down from $9.7 million in FY2012. The Administration requested $5 million for gas hydrate research and development in FY2014.[33]

[31] DOE methane hydrate R&D program, at http://www.netl.doe.gov/technologies/oil-gas/FutureSupply/MethaneHydrates/rd-program/rd-program.htm.

[32] DOE budget justification documents for FY2005 through FY2014. See, for example, the FY2014 budget justification, http://energy.gov/cfo/office-chief-financial-officer#Detailed%20Budget%20Justifications.

[33] For more detail on DOE gas hydrate R&D activities and results, see Ray Boswell, DOE/NETL, *Gas Hydrate Program Activities in FY2013*, presentation to the Methane Hydrate Federal Advisory Committee, June 7, 2013, http://energy.gov/sites/prod/files/2013/06/f1/Ray%20Boswell%20-%20Gas%20Hydrate%20Program%20Activities%20in%20FY2013.pdf, and Methane Hydrate Advisory Committee (MHAC) Meeting minutes, June 6-7, 2013, http://energy.gov/sites/prod/files/2013/07/f2/Minutes%20of%20June%206-7%20MHAC%20Meeting.pdf.

Field Testing

Alaska North Slope

DOE funded a field trial conducted by ConocoPhillips on the North Slope of Alaska to test if gas hydrates could be recovered using two methods: (1) exchanging methane in the gas hydrate formation with carbon dioxide pumped down the well, and (2) depressurizing the formation to release methane from the gas hydrate formation. The test well, named Ignik Sikumi #1, was drilled in 2011 and the test was performed between January and May 2012. The production testing successfully recovered methane using both methods. The final report concluded that wellbore conditions must be effectively managed to produce methane efficiently from gas hydrates; namely, the temperature, pressure, fluids, and solids in the well would need to be dealt with to enhance the production of methane.[34] Although the test successfully showed that methane could be produced using two different methods in an actual gas hydrate field and not under controlled laboratory conditions, it appears that further work is needed before gas hydrates can be commercially exploited in permafrost regions.

According to the Alaska Department of Natural Resources, the state of Alaska is offering 26,000 acres of state lands on the North Slope for use in long-term research on gas hydrates in cooperation with DOE.[35] The lands could be used for long-term field tests of gas hydrate production, similar to the ConocoPhillips test that concluded in 2012. The announcement follows the signing of a memorandum of understanding between DOE and the Alaska Department of Natural Resources in April 2013 to foster and support unconventional energy research in Alaska, which includes gas hydrates research.[36]

Japan

According to news reports, Japan's Oil, Gas and Metals National Corporation (JOGMEC), announced that it had produced methane from gas hydrate deposits 300 meters below the seafloor in the Eastern Nankai Trough off the east coast of Japan.[37] JOGMEC reported that it conducted a flow test from March 12 to March 18, 2013, and produced methane by depressurizing the formation. According to company reports, this was the first offshore production test of gas hydrates ever conducted.[38] The production of natural gas from gas hydrates is potentially crucial to Japan's future energy supply as the country has shut down nearly all of its nuclear reactors after the March 11, 2011, tsunami and resulting Fukushima nuclear plant disaster. Japan relies on liquefied natural gas (LNG) imports for nearly all of its supply of natural gas and is the world's

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[34] David Schoderbek et al., *ConocoPhillips Gas Hydrate Production Test*, U.S. Department of Energy, National Energy Technology Laboratory, Final Technical Report, July 20, 2013, http://www.netl.doe.gov/technologies/oil-gas/publications/Hydrates/2013reports/nt0006553-final-report.pdf.

[35] Alaska Department of Natural Resources, Press Release, *North Slope Oil and Gas Tracts Set Aside for Methane Hydrate Research*, July 31, 2013.

[36] See http://dnr.alaska.gov/commis/priorities/Signed_MOU.pdf.

[37] Ambrose Evans-Pritchard, "Japan Cracks Seabed 'Ice Gas' in Dramatic Leap for Global Energy," *The Telegraph*, March 12, 2013, http://www.telegraph.co.uk/finance/newsbysector/energy/9924836/Japan-cracks-seabed-ice-gas-in-dramatic-leap-for-global-energy.html.

[38] Japan Oil, Gas and Metals National Corporation (JOGMEC), news release, Flow Test from Methane Hydrate Layers Ends, March 18, 2013, http://www.jogmec.go.jp/english/news/release/news_01_000005.html.

largest LNG importer.[39] Since the Fukushima disaster, Japan has increased its reliance on imported natural gas to record levels.[40]

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[39] U.S. Energy Information Administration, *Overview Data for Japan*, June 4, 2012, http://www.eia.gov/countries/country-data.cfm?fips=JA.

[40] Ambrose Evans-Pritchard, "Japan Cracks Seabed 'Ice Gas' in Dramatic Leap for Global Energy," *The Telegraph*.